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Species introductions and reintroductions, faunistic and genetic pollution: some provocative thoughts[1]

Alain DUBOIS

Vertébrés: Reptiles & Amphibiens, USM 0602 Taxonomie & Collections,
Département de Systématique & Evolution, Muséum national d'Histoire naturelle,
25 rue Cuvier, 75005 Paris, France
<adubois@mnhn.fr>

Although less than other animal groups, amphibians are sometimes concerned by the problems related to the introduction of alien specimens into natural populations. They may be victims of such introductions (especially of amphibians, fishes and other aquatic predators), or cause problems to other species through introduction outside their range. The problems posed by introductions, reintroductions and population reinforcements are discussed in a more general way. Introductions of alien species outside their range (faunistic pollution), or of alien specimens into other populations of the same species or of another interfertile species (genetic pollution), beside creating ecological problems, hinder or impede subsequent study of the history and evolution of these populations. For evolutionary biologists, they amount to a destruction of their object of study. Furthermore, such operations carry an optimistic but misleading message to the public, according to which destructions of the environment caused by human activities would be reversible. It is urgent that the main concepts of genetics and taxonomy be given more weight in decisions regarding reintroductions of animals into threatened populations or habitats.

INTRODUCTION

Amphibian specialists worldwide have recently become aware of two "new" questions (1) our current knowledge of the amphibian species of the planet is very incomplete (KÖHLER et al., 2005), and "it is reasonable to predict that zoologists have not yet collected, studied, described and named half of the amphibian species that still live on our planet, perhaps even much less" (DUBOIS, 2004: 22); (2) amphibians are currently facing major threats of various kinds, so that many species of this group are likely to become extinct in the next decades

1. This paper is a combination of a communication entitled "Les concepts de pollution faunistique et de pollution génétique", presented during the workshop "Les Amphibiens et les introductions d'espèces exogènes dans les milieux" organized by ISSCA and held in the Angers University (France) on 10 November 2003, and a communication entitled "Le concept de pollution génétique", presented during the workshop "Espèces envahissantes - Introductions" organized by the Société de Biogéographie et held in the Paris Museum (France) on 19 November 2004

(STUART et al., 2004, LANNOO, 2005) – many of them even before having been described (DUBOIS, 1997; HANKEN, 1999). Batrachologists feel therefore very concerned about the conservation of amphibian species, and, when this is impossible (especially when their habitats are being destroyed), they try at least to collect some specimens as a testimony to the existence of a species before its destruction as a result of human activity. Because of their complex life cycles, amphibians are particularly sensitive to environmental perturbation or destruction, being liable to be aggressed either during their aquatic life (as tadpoles or breeding adults in many species) or during their aerial life (as juveniles and adults). For this reason, in the recent decades attention has particularly be given to the factors of threat of these animals linked to the destruction or alteration of their habitats. Less interest has been afforded to another question, more studied in other groups of animals like mammals or birds, i.e., the problems posed by the displacement of animals by man on our globe and their introduction into new habitats. In this group also, however, this question merits to be considered.

Amphibian populations are concerned by this problem either as introduced species or as victims of introductions of alien species or specimens in ecosystems. Compared to mammals and birds, few amphibian species have been introduced in many regions outside their distribution range, but three of them have been so in several parts of the world: *Xenopus laevis* (Daudin, 1802), *Bufo marinus* (Linnaeus, 1758) and *Rana catesbeiana* Shaw, 1802. In some cases, these introductions were documented to have negative impacts on the native populations of other species of amphibians, or of other zoological groups. In other cases, for want of comparative studies, in particular based on the survey of the same habitats before the introduction, no such impact is known to have yet occurred, but a simple application of the *precautionary principle* requires to be very prudent before considering such an impact as negligible. Calling such a careful attitude "psychosis" (DUGUET & MELKI, 2003), without strong data demonstrating that the introduction has no harmful effect of any kind on an ecosystem, is certainly not doing a service to the education of the public to the risks of ecological desequilibria linked to the introduction of alien species in ecosystems. Other introductions of amphibians, more limited in scope, have occurred in various regions, some of them with a documented negative impact on the native populations. The latter is particularly strong in small isolated habitats such as islands, as well exemplified by the introduction of the hylid species *Osteopilus septentrionalis* (Dumeril & Bibron, 1841) in the Caribbeans (BREUIL, 2002).

Amphibians can also be the victims of the introduction of alien species or specimens in habitats. Introduction of other aquatic predators like fishes or crayfishes can have strong impact on amphibian populations, in particular those in which a large part of the life cycle is spent in water, such as some mountain lake newt populations (DUBOIS, 2002). This impact can seemingly be reversed by reintroduction of amphibians in these habitats after eradication of the predators, but this is only apparent, as the reintroduced specimens will have to come from other populations and therefore will not inform us on the evolutionary characteristics of the specimens that had reached these habitats "by themselves".

Although seldom mentioned by ecologists and conservation biologists, this problem of the loss of information caused by displacement of animals is even stronger in the case of specimens of the "same species", or of different species but that are liable to hybridize successfully in the field. A particularly striking example in this respect is that of the complex of European green frogs of the genus *Pelophylax* Fitzinger, 1843 (or the *Pelophylax* subgenus of the genus *Rana* Linnaeus, 1758), which is of particular interest for evolutionary biologists as it includes both "normal species" and kleptons, i.e., "species" of hybrid origin with modified meiosis and hemiclonal transmission of the genome of one parental species to the progeny (DUBOIS, 1977, 1991; DUBOIS & GÜNTHER, 1982, GRAF & POLLS-PELAZ, 1989). Understanding how such a complex system appeared, evolved and progressively spread all over Europe is of great interest, and requires in particular analysis of the phylogeographic relationships between populations of the various taxa and regions of all Europe. Such an analysis will simply be impossible if too many displacements of green frogs are made, either for the purpose of eating frog legs (DUBOIS, 1983), or of using frogs in research and teaching (DUBOIS, 1982), or of simple curiosity or "accident". However, evidence now exists that such displacements, followed by "successful" implantation of the newcomers and their breeding within the local populations, have already taken place in various parts of Europe, which will no doubt obscure or make impossible such phylogeographic analyses (ARANO et al., 1995; PAGANO et al., 2003).

In may be useful for batrachologists to provide a more general discussion of some of the concepts relating to the problems of introductions and mixtures of specimens from alien origins in local animal populations, especially in the light of the concepts of "faunistic" and "genetic" pollution.

DEFINITIONS

The term pollution derives from the Latin verb *polluere*, which means "destroy the purity or sanctity of". It is traditionally used in biology, and especially in environmental sciences, to designate the introduction into an ecosystem of alien elements, i.e., that were not initially part of this ecosystem. The use of this term usually has two connotations. First, this introduction is usually "artificial" (i.e., due to man). Second, it is destructive or harmful to the environment or to the species that live there.

Environmental biology usually considers two kinds of pollutions: chemical and physical. Chemical pollution may be mineral or organic. Physical pollutions may be of various kinds, e.g., thermic, electro-magnetic, acoustic or even visual. The present discussion is devoted to a kind of pollution which is less often considered as such, i.e., *biotic pollution* (DUBOIS, 2002: 49), the *introduction* of alien organisms into ecosystems, following their *translocation* (displacement), which modifies the initial integrity of these ecosystems.

Three major categories of biotic pollutions can be distinguished: (1) the terms *faunistic pollution* (DUBOIS, 1983*a*: 103) and *floristic pollution*, or more generally *taxonomic pollution*, designate introductions into ecosystems of *taxa* that were previously absent from them, (2) the term *genetic pollution* (DUBOIS & MORÈRE, 1979, 1980) refers to the modification of the genetic structure of a population resulting from the introduction of individuals being interfertile with those of this population, (3) the term *cultural pollution* (DUBOIS & MORÈRE, 1980) points to the introduction in a population, through learning or imitation, or behaviours or traditions that were not previously present.

Below, the term "natural" population designates a population that has not been modified by the introduction of alien specimens carried from elsewhere by man. This does not mean that such populations are "natural" in the sense that they would have evolved without any influence from man. Very few habitats, if any, remain on our planet that have not been modified little or much by human activity, but as long as the impact of this activity has been limited to predation, modification of the habitat or other aggressions, it has not altered the population by introduction of alien genetic material. The "original" genetic characteristics of a population are by themselves neither "better" nor "worse" than such "artificially modified" characteristics. Any given local population can be more or less "adapted" to its habitat If all were "best adapted", extinctions would have been much rarer than they have been during the evolution of organisms on earth The idea that is defended below, i.e., that, from the viewpoint of evolutionary biologists, introduction of alien specimens or alleles in populations should not be supported, does not mean that in most cases this introduction could render the receiver population more fragile (although this is true in some cases), but that it will obscure the message which "natural" populations, as defined above, can deliver regarding their past history and evolution

In what follows, the term "receiver population" designates any "natural" population in which individuals coming from another population are artificially introduced by man, whereas "provider population" designates the "natural" population where these introduced specimens have been collected.

Faunistic pollution

Faunistic (or floristic) pollution results from the introduction, followed by *acclimatization* (i.e., successful reproduction), of a species outside its previous distribution area. The criterion of acclimatization is an important one: simple introduction, not followed by reproduction in the new habitat, of a new species, even in large numbers, does not qualify as faunistic pollution, as it does not permanently modify the taxonomic structure of the ecosystem.

Faunistic pollution may have either "negative" or "positive" consequences on the environment and the species that live there.

In a first stage, a "successful" (i.e., followed by reproduction) introduction results in an increase of the species diversity of the ecosystem In a second step, it induces more important modifications in this ecosystem. This may include reductions or extinctions of the populations of other species, i.e., a reduction of species diversity at the expense of "autochtonous" species, resulting from either predation, competition, parasitism or introduction of pathogens, or a combination of these factors. These structural modifications, in their turn, entail modifications in the dynamics of the ecosystem, in the relations between species.

Several criteria can be taken into account to consider that such a consequence is "positive" or "negative" Some criteria rely on the needs or desires of human societies, or of some of their members, whereas others rely on the preservation of some natural equilibria or dynamics. Thus, reduction of specific diversity or modifications in the dynamics of the ecosystem may be considered "negative" consequences for the latter. But the situation is more complex, less straightforward, when the consequences for human societies, groups or individuals are considered.

Since the 19th century, many examples of catastrophic consequences of introductions of alien species into ecosystems have been documented (DORST, 1970, PASCAL et al., 2006). In many cases, an introduced species, having no local predators or competitors, shows a very rapid population growth and quickly invades the neighbouring regions and habitats, hence the term of "invasive species" to designate such situations. To tell the truth, such species are usually not particularly "invasive" by themselves, and often do not show such aggressive expansionist characteristics in their region of origin, but what makes them "invasive" is their arrival in a new ecosystem where they find a "free place" or are, at least temporarily, more efficient than the native species in competition or predation. The impact of such taxonomic pollutions may be very strong, especially in the first years or generations, before a new equilibrium can progressively develop. Particularly severe are the consequences of such introductions in small ecosystems, limited in size and/or in ecological diversity, such as islands, desert oases or isolated habitats. in such cases, extinction of the local species may occur rapidly, before such an equilibrium can even appear

Despite these cautionary tales, still nowadays many "wild" introductions of plants or animals are made in various countries just for the "fun" or for "enrichment" of ecosystems believed to be "too poor in species" (VASSEROT, 1972) More dangerous are such translocations when they are "justified" by "economic" criteria Among results for human societies that can be considered "positive" are the introduction of new food resources: no doubt, the introduction of the large frog *Rana catesbeiana* in some regions with depleted faunae (often as a result of previous human activities) may provide new sources of proteins for local human populations. In some cases, the introduction of alien species into an ecosystem may allow to help destroying other species that are harmful to the crop (parasites) or to live-stock (predators). Such a "biological pest control" is often considered only from the viewpoint of agriculturists and breeders, as a fully "positive" intervention of men on an ecosystem, but it may be so only from a narrow point of view, as introduced species frequently have the "bad idea" to do something else than that for which they have been imported: a striking example is that of the giant toad *Bufo marinus*, initially introduced in various regions in the hope that it would destroy insects harmful to plantations, but which turned to have very destructive impacts on the local ecosystems, especially in Australia.

As for the "negative" consequences for human societies of the modifications of ecosystems that may follow faunistic pollution, those which have direct, "visible" economic impact are often highlighted e g , the loss of food resources, as a result of predation, parasitism, competition or pathology, or the loss of "spectacular" species, particularly large-sized species of mammals and birds. However, while most popular media, or even scientists, will feel very concerned by threats on species like tigers, pandas or eagles, few will worry about the extinction of an obscure subterranean mole, toad or collembola.

A strange fact, which has often struck me as a professional biologist, is the large, almost unanimous, silence of many of my colleagues, even among those who like myself are interested in biological evolution and who study it, about the immediate and inescapable consequence of any faunistic (or floristic) pollution as a factor of *loss of information*. Such "successful" introductions modify the "natural" composition of ecosystems, and in particular the distribution of species. Whereas laymen and some popular media may imagine that the distribution of all species of our planet is "well known", specialists are well placed to know that this is completely wrong. Except for a few well-studied large-sized mammals, birds and a few other large vertebrates, not only the distribution, but, more prosaically, the mere existence of a large majority of the species of our planet is still unknown to biologists (Hammond et al., 1995). Active introduction of species by man outside their previous distribution range will introduce "artefacts" in the distribution of these species. This is all the more problematic whenever the place of the introduction is "not far" from the "natural" range of the species, especially if it is not separated from the latter by a natural barrier like a sea or mountain. As many introductions are carried out "secretly", in many cases the original place of origin and of release of introduced animals (or plants), and their sexes and numbers, are unknown, and doubts can exist about the indigenous nature of specimens later recorded in the same area. A good example of this situation was that of the specimens of the toad *Pelobates fuscus* (Laurenti, 1768) introduced by simple "scientific curiosity" in the early 20th century by Raymond Rollinat in the department of Indre in France, in an area where the species could potentially be thought of occurring "naturally" (Dubois & Morère, 1979): the subsequent discovery of a population in this department (Dubois, 1984, 1998) inevitably rose the question of this population being native or not in this region, a question which has not been solved yet.

Several methodological precautions must be taken before considering the mere possibility to introduce a new species into an ecosystem, be it for "pleasure" or "curiosity" or for economic puroposes. First, it is indispensable to dispose of a reliable description of the "zero condition", i.e., an analysis of the status of the ecosystem before the translocation. Then, one should not feel contented after having studied a few species, measured or estimated a few parameters only, of particular interest for "man", or at least for the agriculturists, breeders or other supposed beneficiaries of the introduction. Estimation of the impact of the introduction, once realized, should be done not only immediately after, but also in the mean and long term.

In a human society which consists of different groups having particular interests and various ideas, it is normal that different opinions exist regarding the need of such and such action. There is nothing surprising in voluntary introduction of alien species into ecosystems being supported by some groups having short term projects or interests, but what is more surprising is that the scientists concerned, in particular the biologists studying the evolution of species, rarely defend, or even express, their own "corporatist" interest as scientists in such questions.

What can, or could, be the viewpoint of scientists on such introductions? No need to say, biologists will require to have solid, reliable scientific data to evaluate the impact of translocations on natural ecosystems and populations. In most cases, the mere principle of the introduction of alien species in localities should be acceptable only for major reasons of public health or alimentation, but excluding curiosity and pleasure. But it would be their right, not to say their duty, to go a bit further and to say that, a priori, biologists, and particularly evolutionary biologists, cannot be in favour of introductions of alien species into ecosystems, for a simple reason of defence of their own activity. Such translocations create artefacts in the distributions of species and, except in the rare cases where the history and particulars of the introduction are well documented, such artefacts may not be recognized as such later. This means that future studies on the distribution and history of the species in the area will be precluded, or, which may be worse, that their conclusions may be completely wrong. For this simple reason, such projects cannot be supported by students of life evolution on earth

GENETIC POLLUTION

Any acclimatization into a population of individuals interfertile with the native individuals results in a genetic pollution, i.e. a modification of the genetic structure of this population As hybridization is often possible in nature between different, but closely related species, genetic pollution may be either intraspecific or interspecific. It may result either in the introduction into the population of alleles that were absent there, or in a modification of the relative frequency of alleles, e.g , with a sudden increase in the frequency of an allele which previously was very rare in this population, or the reverse.

Genetic pollution may result from transportation (sometimes involuntary) and subsequent release into a population of alien specimens of the same species (or of a closely related, interfertile species) by someone thinking that, as they are supposed to be "the same species", they are "identical", and that "no harm" can result from mixing them Such cases of genetic pollution are so to speak unintentional and little conscious or unconscious. But nowadays a fully conscious and voluntary case of genetic pollution results from actions of conservation biologists aiming at "reinforcing" threatened populations. Such cases have become quite common in the recent decades, and they are supported by a number of actors, so they deserve a particular discussion

Population reinforcement is considered a useful measure of conversation biology in the cases of populations very reduced in size and threatened by extinction, a good example of which is given by the bears in the French Pyrenees. Even when the factors responsible for the reduction in size of the population are no more active (which is rarely the case), many biologists think that a very small population is too fragile to expect rapid size increase. A factor is often invoked as a major one for the weakening of such small populations, and this is the risk of consanguinity. Many population geneticists are keen of mathematical models "demonstrating" that the risk of inbreeding is so strong in such small populations that it is vital to introduce "new blood" to rescue them It is often on the basis of such impressive models and calculations that the decision is taken to introduce specimens of the same species (sometimes referred to the same subspecies) to "reinforce" this population, increase its genetic diversity and save it from sinking into inbreeding. No discussion is often devoted to the fact that any introduction into a population of alien individuals that will breed with the native specimens will result in a modification of the genetic structure of the population that will obscure its evolutionary characteristics.

Many of the promoters of such reinforcement programmes act as if, as soon as they "bear the same name", all individuals of the same taxon are identical and interchangeable. Such an attitude reminds the beginnings of natural history, when a "typological" or "essentialistic" concept of biological species was prevalent It has been completely outdated since the beginning of the 20^{th} century, when the notions of genetic variability and of genetic transmission of characters appeared, which resulted in the progressive appearance of a populational concept of species, developed in the "new systematics" of the 1940s (MAYR, 1982, 1997). It is now well-known that each species is characterized by a large genetic polymorphism, most genes co-existing within the genome of the species under different alleles. Different populations of the same species, especially if they are largely separated and if gene flow between them is limited, may have different alleles, and/or different allelic frequencies. Polymorphism was defined by FORD (1945) as "the occurrence together in the same habitat of two or more distinct forms of a species in such proportions that the rarest of them cannot be maintained by recurrent mutation". Concretely, the term "genetic polymorphism" is often reserved to the description of situations where several alleles have a proportion of at least 5 % in the population, whereas alleles with a lower frequency are considered "rare" (LAMOTTE, 1974): such "rare mutations" can result from recent events of mutation or exceptional immigration from populations having different genetic characteristics. It is now widely accepted that the genetic characteristics of populations of a given species result from an equilibrium between adaptive and neutral characters. Some alleles may be selected because they are advantageous to the population in given conditions of climate, habitat, interactions with other species of the same ecosystem, etc. Others are simply the result of random drift and have no known adaptive effect. The proportion of both kinds of polymorphism is usually not known, and is probably most variable from one species or population to another.

Of course, the genetic pools of natural populations are not stable. They are permanently submitted to important variations, as a result of the phenomena of mutation, selection, and migration for populations that are not isolated. These variations allow them to adapt to changes in the environmental conditions, and species likely to be submitted to frequent such changes show more genetic polymorphism than those inhabiting very stable environments. But in all cases these changes are continuous, they occur from one generation to the other, each generation starting from the genetic pool of the preceding one. In order for biologists to be able to detect and analyse these phenomena, to understand the phenomena of polymorphism, speciation, colonization, migration, the genetic characteristics of populations, that result from the evolutionary process, should not be modified by man through what can be considered an "artificial migration".

A "population reinforcement" may have several consequences on the population which receives such artificial immigrants. Some are "positive", at least initially, in ecological, ethological and demographic terms. The increase in the population size not only reduces the risks of complete extinction by death of the last survivors. It usually increases the genetic diversity, but also, and perhaps mostly, the chances for adults of both sexes to meet and to have successful breeding. But it may also have "negative" ecological consequences, such as the introduction of pathogens, or the invasion of the genome of the population by alleles less adapted to the local conditions. In all cases, anyway, it results in a modification of the genetic characteristics of the population (genetic pollution).

Now, let us consider another aspect of this question, seldom mentioned in publications dealing with conservation biology, but similar to the one tackled above for taxonomic pollution. From the viewpoint of the biologists who study evolution, genetic pollution simply amounts to the destruction of one of the objects of their studies. Contrary to researchers of all other "reductionist" disciplines of the science of biology, evolutionary biologists do not have the possibility to make and repeat experiments on their material. Of course, they can study drosophiles in cages, build up models that are supposed to account for some of the evolutionary facts observed, but these facts themselves are beyond their possibility of action, for the simple reason that they occurred over millions of years. Biological evolution is a unique experiment that has occurred only once and which cannot be repeated. (Furthermore, if it was to be repeated, the results would be completely different from those we observe now, as this historical process was in no way teleological and is the result of an unrepeatable mixture of chance and natural selection). The only way to understand this experiment is to study carefully its results, all its results, not only in terms of morphology, anatomy, genetics, etc., but also in terms of geographical distribution of the organisms and of the historical patterns of their phylogeny. In this respect, genetic pollution acts as a parasite: it introduces in the patterns of nature some "artefacts" that will often be impossible to recognize as such later on. As well analysed by GREIG (1979), this is not a matter of "purity" of the receiver population, that should be protected from outsiders because they would be "bad" - an idea which understandably reminds nauseous iodeologies of racism in human society: it is "simply" a matter of deliberate destruction of a product of evolution that could help evolutionary biologists to understand some of the modalities of organismic evolution on our planet.

The claimed purpose of introduction of alien specimens into a threatened population is to "reinforce" the latter. However, the first immediate consequence of this action is to modify the original characteristics of the population, in such a way as these characteristics will remain forever impossible to know, or very hazardous to reconstruct. From the viewpoint of an evolutionary biologist, genetic pollution results in *destroying* the population as such. Specimens referred by taxonomists to the same taxon (species, subspecies) may still occur in the habitat in the future, but these won't be the progeny of the "natural" population which once occupied this site.

What are, or what should be, the aims of conservation biology? Are they to help keeping biological diversity as high as possible for ecological purposes (according to the idea that an ecosystem with a high specific richness is more healthy and resistant than a poorer one)? Are they to protect the species for patrimonial reasons, for their intrinsic value or interest? To conserve the species as witnesses of biological evolution? To maintain as many "natural" populations as possible in order to be able to understand in detail evolution? If the reply to the latest question is yes, then voluntary genetic pollution through "population reinforcement" is contradictory with this aim.

REINTRODUCTIONS

A different question is that of *reintroductions* of species in a region where they used to be present in recent historical times (often until the 19th or 20th century), but where they became extinct as a result of human activity. In such cases, the reintroduction of specimens may be considered as a possible way to reinstate a situation similar to the previous ones, but a number of precautions must be taken before doing so (JOIRIS & TAHON, 1971, RAPPE, 1977). First of all, it is necessary to establish for which reasons the species first came to extinction in this region. If the cause of this extinction still persists, there is no point in reintroducing the species, as it will probably follow the same fate as previously. Then, if the conditions have changed and are again compatible with survival of the species, the next question is to know why the species did not come back by itself. It may be because the next populations of the species are too far, or separated from the population concerned by barriers that the species cannot overcome. If so, reintroduction may be the only way to reinstate the species in the receiver locality, but if not, it may just be a matter of time: waiting enough will allow the species to come back by itself in this area. If for some reason one would like to "go quick" and to reintroduce the species artificially to "save time", then another future development of the situation may be that finally specimens come from another population of the species: they will then meet the specimens reintroduced, or their descendants, and we will then be sent back to the case discussed above of genetic pollution between two populations. The reverse possibility also exists, that of specimens reintroduced into a receiver population which later move and come in contact with other populations. This is not impossible even over long distances, in particular in the case of birds and mammals. Therefore, in many cases there exists no real difference between reintroductions and population reinforcements, as both may result in genetic pollution of some populations.

Conservation biology, taxonomy and the media

Even if few conservation biologists would spontaneously recognize it, no action in their domain (like in many other fields) would be possible without a taxonomy of living organisms. Decisions are often based on "red lists" and other documents that rely on taxonomic knowledge. Whenever a population is considered threatened, this is on the basis of its allocation to a taxon (species, subspecies). However, this recourse to taxonomy is often "unconscious" and is often accompanied by a negative attitude towards the discipline of taxonomy (Dubois, 2003). Strangely and contradictorily, this negative attitude is accompanied by an unwarranted confidence in the quality and completeness of our taxonomic knowledge, supposed to have been "finished" long ago, and which is considered a solid basis for undertaking actions of population reinforcement.

There are several distinct and complementary reasons why the fact that they "bear the same name" does not mean that two or more populations are "identical". The first one, tackled above, is the existence in all animal species of a genetic polymorphism, and of differences in this respect between different populations of the same taxon. Second, in many zoological groups, different species may exist which cannot be readily distinguished without recourse to rather heavy techniques like bioacoustics, cytogenetics, electrophoresis, nucleic acid sequencing, morphometrics, etc. Such "cryptic species", "sibling species" or better *dualspecies* (Bernardi, 1980) cannot be readily recognized by superficial observation of the phenotype, and mixing them in a single population can result in considerable genetic pollution. If the receiver population happens to be the last one in existence of its species, then its "reinforcing" results in fact in its immediate and irreversible destruction. Another problem comes from the frequent use, at least in some taxonomic groups, of the rank "subspecies", which do not often correspond to a real evolutionary unit. For some people, subspecies correspond to closed black boxes with homogeneous content, variability existing only between such boxes, but not inside each of them: this is again a typological conception of taxonomy that is completely obsolete nowadays (DUBOIS, 1983*b*)

Such attitudes and actions take their roots in ignorance of a major problem faced by biology today, the *taxonomic impediment* (ANONYMOUS, 1994). The latter is both quantitative and qualitative. It is quantitative, because only a small proportion of the animal species of our planet have yet been discovered, collected, studied, described and named. Less than two millions animal species have been described and named so far, whereas the total number may be between 10 and 100 millions, or even more (HAMMOND et al., 2005). The taxonomic impediment is also qualitative, as even for most named species, the amount of information available is very small, and often wrong: most revisionary taxonomic works carried out on zoological groups result in modifications, sometimes drastic, of the taxonomic arrangement of previous authors, in description of new species, synonymisation of others, etc. According to STUART et al (2004), 30 % of the "known" amphibian species worldwide are "data deficient" regarding their conservation status, which means that we know almost nothing about them Although most biologists, including conservation biologists, are convinced that our taxonomic knowledge is solid and likely to be stable, no competent taxonomist would support this interpretation, and specialists of this discipline are the first ones to claim that their results are to be to taken with caution, just like provisional data or "progress reports" Thus, basing interventions like population reinforcements on the current taxonomy of a group, especially when the latter has not been recently revised, is at best naive and at worse irresponsible.

This question is a very enlightening one regarding the relationships which exist nowadays in our society between science, teaching and information, three domains which have different relationships to time. The media (journals, radio, television, and now internet) live under a permanent constraint of "immediateness", with very little interest in the past or the future. For many journalists and reporters, the idea that some questions are still unsolved is simply insupportable, and they require immediate replies, and if possible immediate actions. This "impatience" of the media is incompatible with many problems, in particular regarding environment A second imperative of communication through the media is that, to be likely to reach the public, the "message" must end with a "positive", "constructive", "optimistic" conclusion. Just like many movies have a "happy end" to please a majority of spectators, a message regarding environment would be unbearable if it did not end with a promise that "man", after having destroyed much of our planet, will prove able to repair its faults. The idea that many of the destructions that our societies have caused to the planet where we live are not repairable, that there is no "consolation" to expect, is not acceptable by many.

Thus, the message that many media pass to the public, and to decision makers of our society, is that, yes indeed, "we" have done a lot of mistakes, but that most of the destructions "we" have done are temporary and repairable In this respect, both reintroductions and population reinforcements appear as ideal operations for "man" to correct its mistakes and repair nature after having mistreated it.

Let us take one example, discussed in detail by DUBOIS & MORÈRE (1980), that of the Atlantic puffins, *Fratercula arctica* (Linnaeus, 1758), of the Sept Iles in Bretagne (France) Following the wreck of the super-tanker Amoco Cadiz in 1978, their population had dropped to about 430 couples, which had been judged "too small" by some ornithologists, who decided to "reinforce" it by introducing specimens collected in the Feroe islands (north of Scotland). This operation was all the more questionable that the Sept-Iles population was a very isolated one, the most meridional of the species, and had never been seriously compared with the more northern ones from various viewpoints (genetic, cytogenetic, behavioural etc.). Furthermore, this population was known to have already suffered a severe depletion because of hunting. Although at the end of the 19th century it was estimated to 10000-15000 couples, it had dropped already to 300-400 couples in 1911 when hunting was prohibited on these islands. it then progressively raised again to 7000 couples in 1950. Just "leaving the population alone" and trying to avoid further oil pollutions could have allowed a similar process to take place, but of course this would have taken a few decades, during which there would have been few birds to show to visitors, ornithologists and tourists. In contrast, some ornithologists organized a very "mediatic" operation to collect just hatched birds in the Feroes, carry them back to France and release them in the Sept-Iles. No doubt, in our times where many laboratories have difficulties finding funds for their research, such a "dramatic" operation filmed by televisions is easier to finance than would have been research on the characteristics of the isolated Bretagne population of puffins. These characteristics might remain forever impossible to know, if only few Feroe birds survived and bred with the local ones, which could have been enough to modify the genetic particularities of the population. However, it is not clear if any of the introduced birds survived until adulthood (REILLE, 1990), and now everybody agrees that this introduction of alien specimens was a bad idea, both for genetic and ecological reasons (CADIOU et al., 2004).

Similar operations have been organized with various large and spectacular species, e.g., in France, with lynx, bear or vultur. In the case of Pyrenean bear, *Ursus arctos* Linnaeus, 1758, many discussions raged among zoologists, conservation biologists, journalists and state officers to decide whether or not bears from other parts of Europe should be introduced to "reinforce" the vanishing local population. Most of the discussions turned around the problem of the number of individuals that should be transferred to avoid "genetic inbreeding", and elaborate mathematical models were produced in this respect. Few of the decision-makers, however, seemed to be aware that the Slovenian bear provider populations seem to belong in a phylogeographic lineage different from that of the Pyrenean population (TABERLET & BOUVET, 1994, MILLER et al., 2006), although some studies seem to indicate that such a phylogeographic pattern does not exist, or at least that the situation is more complicated and needs more research (PÄÄBO, 2000. HOFREITER et al., 2004). Here also, it is unlikely that these introductions will be successful, as many local people are unfavorable to the reintroduction of bears in this pastoral region, and tend to harass and even kill them. But if it did "succeed", i.e., if Slovenian bears did breed with Pyrenean bears, then the local population could definitely be considered extinct, even if "bears" could still be seen in these mountains. It could therefore not be useful anymore to try and understand the history of bears in western Europe.

The idea that "having bears" or "seeing puffins" in an area is equivalent to having preserved or restored a natural population seems strange to evolutionary biologists. Such artificial populations created by mixing individuals from various origins (even sometimes unknown origins, as was the case for some specimens in a program of "reintroduction" of vultur in southern France which used captive birds from various zoos, TERRASSE, 1990) may play a temporary rôle to preserve a species in an extreme situation when only a few specimens remain alive over the whole range of a species, but they are not justified when other healthy populations still exist elsewhere (as is the case in most of the species mentioned above). Once modified by such genetic pollution (and sometimes also cultural pollution, when different local behaviours can be transferred by imitation), the receiver population will provide little or no information on its evolution and history

Let us take a comparison from another domain Imagine a quarry that has long been known to be rich in paleontological remains, so that many collectors visited it and removed fossils from it. If the deposit comes to be exhausted, the owner may be unhappy, for example because he held a refreshment bar nearby that is now short of customers. He may then decide to take a truck, go to another quarry in another region, collect many fossils that "look the same" and discharge them in his quarry Visitors may come again and some of them may be happy because they see and collect fossils, but the latter, being disconnected from their original deposit and strates, will carry much less information than in their original site: they will still provide data on their morphology and characters, but this information won't be connected to geographical and stratigraphical, hence historical, data. Even worse, if a collector ignores their origin and collects these specimens thinking that they are in their original site, he may draw unwarranted and completely false conclusions. To be sure, visitors turning around the Sept-Iles in boats may be happy to "see puffins", but, if the introduction had been successful, the latter would not tell us much on the history of the puffin population of these islands. They would be quite similar in this respect to specimens in zoos, aquaria and terraria. are the latter the only possible future for all biodiversity on this planet?

When we first developed these ideas (DUBOIS & MORÈRE, 1980; DUBOIS, 1983*b*), the reconstruction of the history of populations of a given species was still a promise, but nowadays, with the development of molecular methods based on nucleic acid sequencing, the new discipline of *phylogeography* has developed. The idea that was then largely theoretical has now become a common one, and more and more works are produced in this promising direction It is therefore particularly shocking that, in the meanwhile, these ideas have not yet found their way in the minds and actions of conservation biologists.

When discussing with conservationists, it is striking to realize that one of the main arguments they put forward to justify actions of population reinforcement is the risk of consanguinity in populations too small in size. Also striking is the fact that one of the few universal taboos in all human societies is the prohibition of incest Could it be that this taboo has something to do with the strong aversion, not to say the phobia, of consanguinity and inbreeding, by many conservationists (GREIG, 1979, DUBOIS, 1983*b*)? The idea that a genetic load, increased at each generation by inbreeding, can lead a population quickly to extinction because of the growing rate of "abnormal" individuals, seems to come in part from experiences in human populations or in domestic animal strains, such an increase is possible in humans because natural selection is highly reduced in our societies, disabled individuals being able to survive thanks to the help and support of the group, in cattle and other domestic animals, some selection exists, but highly directional as compared to wild conditions. In wild animal populations, deficient individuals are counter-selected at each generation, and usually leave no offspring Although no doubt mathematical models based on the theories of genetic populations support this interpretation, these often rely on many assumptions that are difficult to test The validity of such models would be strengthened by empirical, observational or experimental data, but such data are not very numerous, or not very convincing. In many cases, other explanations can be proposed to account for extinction of very small, isolated populations (Greig, 1979). In fact, the existing empirical data rather seem to indicate that populations may well survive periods of very small size, with reduced genetic variability.

Several well-known examples support this interpretation. In captivity or semi-captivity, just a few individuals may be enough to start a wealthy stock, the most famous example being perhaps that of the European bison, a species which was rescued from just a few individuals kept mostly in the Białowica forest in Poland (Dorst, 1970). It may be argued that in this case their breeding was under the protection of humans, who may have eliminated some disabled animals, but no evidence for this is known. Another well-known situation, in which, on the contrary, the help of humans cannot be called upon, is that of the so-called invasive species mentioned above. In most known cases, invasive populations only started from a very small number of individuals, i.e., with a very reduced sample of the complete genetic variation of the species. Despite their high rate of inbreeding, these populations not only survived, but were able to have an explosive demography and to invade large territories in a short period of time. Colonization of islands by terrestrial animals also often starts from very low numbers of invaders, sometimes a single fertilized female. Small isolated groups of animals are not necessarily condemned to extinction because of inbreeding. In some cases their small number and reduced sampling of the total gene pool of the species may lead such small groups of animals to settle a new colony having unusual characters compared with their initial population. Such a founder effect by small number of individuals has long been known to be a common mode of speciation in islands or various isolated "ecological islands". But this is not the only possible pattern of evolution, as not all isolated small populations show this phenomenon of genetic drift.

Genetic and taxonomic conservation

Conservation biology is and will be more and more a crucial domain in the beginning "century of extinctions" (Dubois, 2003). However, to play fully its rôle, this discipline must make more use than it does today of concepts from other domains of biology. It will not be enough to conserve or protect "kinds" of animals and plants. Conservation biology must incorporate some basic concepts of taxonomy and genetics, such as the existence of genetic polymorphism within species, of sibling species, and more largely the mere recognition of the taxonomic impediment as a basic problem for any action regarding biodiversity nowadays. The concepts of "genetic conservation" and "taxonomic conservation" must be given a more important place than that they have today in conservation biology.

The idea that "mankind" as a whole is homogeneous, and composed of individuals and groups which all have the same characteristics, interests and projects, although doubtless generous, is of course a complete dream. Different nations do exist, and within each country, different social classes and many other groups of people. Each of these units has its own interests and aims. These groups tend to be represented and defended by organizations at various levels, like states, political parties, trade-unions, lobbies, trusts, or clandestine organizations. Conservationists are well organized at national and international level, their opinions can be heard in many cases, and they succeed in reaching some of their aims, including in organizing operations of "species reintroductions" or "population reinforcements". In contrast, it seems strange that, in this domain where evolutionary biologists can be expected to play an important rôle, at least as providers of basic information on the biodiversity, they do not act more as a "social group" by itself, with their own needs and projects. One such need and project would be to try and keep as many testimonies as possible of the evolution of organisms on earth, and among these testimonies, the existence and characters of animal populations in different parts of the planet is an important one. Accepting to participate in operations that, in the end, result in destroying the identity of "natural" populations, thus precluding their subsequent study, amounts for evolutionary biologists to destroying their own object of research. They may decide to do so, but at least this seems to be a matter worth of being discussed first (DUBOIS, 1983*b*)

There is another reason for being reluctant to supporting such operations. It is their basic philosophy, and especially the message that such actions deliver to the public. As discussed above, this is a positive, optimistic message: what "man" has destroyed, he is able to repair. This message is completely misleading. First of all, it concentrates on a few large-sized "flag" species, without caring for the many other more obscure species that usually face the same threats and extinction factors. But above all, it is a deceiving message, as it tends to persuade the public that restoration of "natural" conditions is possible without changing basically the relationships between human societies and nature. Whatever our societies decide to do in the future, tropical forests, humid zones and other ecosystems that have been destroyed in the last century won't reappear, at least in the period of time of our generations, and of many other generations to come. The millions of species that our societies have aleady and will have caused to be extinct by the end of this century are and will be extinct forever, and most of them won't have ever been collected by scientists for future study by the forthcoming generations of taxonomists, as this question is considered of little interest by the decision-makers of our societies today (DUBOIS, 2003, 2007) All of this is a consequence of the "choices" made by our societies, although in this case the term "choice" is a bit misleading, as many actors of this catastrophe do not even realize what they are doing But, then, what should be the rôle of those who have some knowledge (scientists) and of those who have some power to "communicate" (people in the media, the press, etc)? Is this to make believe that the moon is made of green cheese, and to convince people that we will have stopped the erosion of biodiversity on earth by 2010, although deforestation, CO_2 emissions and other pollutions, and human demographic growth will go on? Is it to tranquillize those who worry about species extinctions by telling them that animal species are "adaptable" and will follow the climatic and other environmental changes, and that anyway if they do not succeed in doing so this is not very important, as our planet has already gone through several mass extinction periods and that it has not impeded "life" to go on? This last statement is about as intelligent as would be a fireman who would refuse to come when warned that a fire has started in a house, as other houses have already burnt in the past and this has not impeded "life" to go on. Should scientists and media people remain silent and "optimistic" in order not to disturb the activity of stockholders of car and petrol industry, timber companies, fisheries or agronomical trusts? However unpleasant this may seem to some, it should be clear that nature conservation is possible only through confrontation with social forces that have other personal interests

(Dubois, 1983*a-b*)[2] The "angelic" attitude which consists in saying that everybody is nice and kind, that companies that have been destroying the planet for decades will now save it, "restore" what they have ravaged, is either naive or deliberately misleading. It will not help our children to struggle to save what will remain of nature on our planet largely devastated by human activity

The ideas of genetic and taxonomic conservation are not new. As pointed out by Dubois & Morère (1980: 16), such ideas were already formulated very clearly more than one century ago, e.g. by Bedriaga (1892: 244). Nevertheless they are still unknown, or misunderstood, by many biologists. In some cases, like in the case of alligators in the USA (references in Dubois & Morère, 1980), hot discussions may rage for some time between supporters and adversaries of displacement of animals from populations to others, the latter insisting that such translocations provide "the possibility of obscuring natural patterns of adaptation and evolution" (Ross, 1977). But in many cases, like those mentioned above of puffin or vultur, no such discussion was carried out before the decision of translocation was taken.

It has now become urgent that these ideas become more present in the field of conservation biology, and the latter field should not be left only in the hand of "specialists" who have no knowledge in other fields of biology. In most cases of "endangered" populations, there is no point in adding specimens in the population if the causes of threat have not been eradicated Struggling for suppressing or reducing these causes is indeed a justified aim for conservation biology. But, once this is done, enough time should be left to the population to reconstitute its stock by itself, without incorporating "new blood". This may take years and decades, and sponsors and journalists may not like it, but do we work to please sponsors and journalists? Of course, even if they have been given a chance to reconstitute by themselves, some of these very reduced populations may get extinct anyway. It will then be time to study the opportunity of reintroducing the species, if it is unable to recolonize the site by itself. But in some other cases, we will indeed have acted in a responsible manner to preserve a small part of the patrimony that was bequeathed to mankind by biological evolution, but that our societies have largely spoiled and destroyed.

Literature cited

Anonymous [Systematics Agenda 2000], 1994 *Charting the biosphere a global initiative to discover describe and classify the world's species. Technical report* New York, American Museum of Natural History, American Society of Plant Taxonomy, Society of Systematic Biologists & the Willi Hennig Society: 1-34

Arano, B., Llorente, G., García-París, M & Herrero, P., 1995 Species translocation menaces Iberian waterfrogs. *Conserv. Biol.*, **9** (1), 196-198.

Bedriaga, J de, 1892 Lettre a M le professeur Anatole Bogdanow (A propos de l'importation et du croisement des reptiles et des amphibiens) *Congres international de Zoologie Moscou*, Premiere partie: 244-245

2 The resistance to these ideas does not always come from where one would expect In the eighties, on several occasion we were forbidden to take part and speak in meetings and congresses on these questions organized or sponsored by the French Ministry of Environment In one case we had even paid the inscription fees to the meeting (Lecomte et al., 1990) and for the hotel room, a payment for which we were never refunded, but we were not allowed to attend and speak

BERNARDI, G., 1980. – Les catégories taxonomiques de la systématique évolutive. *In:* C. BOCQUET, J. GÉNERMONT & M. LAMOTTE (ed.), *Les problèmes de l'espèce dans le règne animal*, **3**, *Mém. Soc. zool. Fr.*, **40**: 373-425.

BREUIL, M., 2002. – *Histoire naturelle des Amphibiens et Reptiles terrestres de l'archipel guadeloupéen: Guadeloupe, Saint-Martin, Saint-Barthélémy.* Paris, MNHN, Patrimoines naturels, 54: [i-iii] + 1-339.

CADIOU, B., PONS, J.-M. A YESOU, P. (ED.), 2004. – *Oiseaux marins nicheurs de France métropolitaine (1960-2000).* Mèze, Biotope: 1-218.

DORST, J., 1970. – *Avant que nature meure.* Neuchâtel, Delachaux & Niestlé: 1-540.

DUBOIS, A., 1977. – Les problèmes de l'espèce chez les Amphibiens Anoures. *In:* C. BOCQUET, J. GÉNERMONT & M. LAMOTTE (ed.), *Les problèmes de l'espèce dans le règne animal*, **2**, *Mém. Soc. zool. Fr.*, **39**: 161-284.

----- 1982. – Notes sur les Grenouilles vertes (groupe de *Rana* kl. *esculenta* Linné, 1758). I. Introduction. *Alytes*, **1**: 42-49.

----- 1983*a*. – A propos de cuisses de Grenouilles. Protection des Amphibiens, arrêtés ministériels, projets d'élevage, gestion des populations naturelles, enquêtes de répartition, production, importations et consommation: une équation difficile à résoudre. Les propositions de la Société Batrachologique de France. *Alytes*, **2** (3): 69-111.

----- 1983*b*. – Renforcements de populations et pollution génétique. *C. r. Soc. Biogéogr.*, **59**: 285-294.

----- 1984. – *Pelobates fuscus* dans le département de l'Indre. *Alytes*, **3** (3): 137-138.

----- 1991. – Nomenclature of parthenogenetic, gynogenetic and "hybridogenetic" vertebrate taxons: new proposals. *Alytes*, **8** (2): 61-74.

----- 1997. – Editorial: 15 years of *Alytes*. *Alytes*, **14** (4): 129.

----- 1998. – Mapping European amphibians and reptiles: collective inquiry and scientific methodology. *Alytes*, **15** (4): 176-204.

----- 2002. – Les amphibiens et les introductions d'espèces allogènes dans les milieux. *In: Gestion et protection des amphibiens: de la connaissance à la prise en compte dans les aménagements*, Paris, AFIE: 49-69.

----- 2003. – The relationships between taxonomy and conservation biology in the century of extinctions. *Comptes rendus Biologies*, **326** (suppl. 1): S9-S21.

----- 2004. – Developmental pathway, speciation and supraspecific taxonomy in amphibians. 1. Why are there so many frog species in Sri Lanka? *Alytes*, **22** (1-2): 19-37.

----- 2007. – Un nouveau paradigme pour la biologie au 21e siècle. *Biosystema*, in press.

DUBOIS, A. & GÜNTHER, R., 1982. – Klepton and synklepton: two new evolutionary systematics categories in zoology. *Zool. Jb. Syst.*, **109**: 290-305.

DUBOIS, A. & MORÈRE, J.-J., 1979. – A propos des introductions d'espèces réalisées par Raymond Rollinat. *Bull. Soc. herp. Fr.*, **9**: 59-61.

----- 1980. – Pollution génétique et pollution culturelle. *C. r. Soc. Biogéogr.*, **56**: 5-22. Reprint: *Bull. AFIE*, 1982, **3**:10-14.

DUGUET, R. & MELKI, F., 2003. – *Les Amphibiens de France, Belgique et Luxembourg.* Mèze, Biotope: 1-480.

FORD, E. B., 1945. – Polymorphism. *Biological Reviews*, **20**: 73-88.

GRAF, J.-D. & POLLS PELAZ, M., 1989. – Evolutionary genetics of the *Rana esculenta* complex. *In*: R. M. DAWLEY & J. P. BOGART (ed.), *Evolution and ecology of unisexual vertebrates*, Albany, The New York State Museum: 289-302.

GREIG, J. C., 1979. – Principles of genetic conservation in relation to wildlife mangement in southern Africa. *S. Afr. J. Wildl. Res.*, **9** (3-4): 57-78.

HAMMOND, P. M., AGUIRRE-HUDSON, B., DADD, M., GROOMBRIDGE, B., HODGES, J., JENKINS, M., MENGESHA, M. H. & STEWART GRANT, W. 1995. – The current magnitude of biodiversity. *In*: V. H. HEYWOOD & R. T. WATSON (ed.), *Global biodiversity assessment*, Cambridge, Cambridge University Press: 113-138.

HANKEN, J., 1999. – Why are there so many new amphibian species when amphibians are declining? *Trends in Ecology & Evolution*, **14** (1): 7-8.

HOFREITER, M., SERRE, D., ROHLAND, N., RABEDER, G., NAGEL, D., CONARD, N., MÜNZEL, S. & PÄÄBO, S., 2004. – Lack of phylogeography in European mammals before the last glaciation. *Proc. natn. Acad. Sci. USA*, **101**: 12963-12968.

JOIRIS, C. & TAHON, J., 1971. – Le problème de l'introduction et de la réintroduction des espèces animales. *Aves*, **8** (1): 14-17.

KÖHLER, J., VIEITES, D. R., BONETT, R. M., HITA GARCÍA, F., GLAW, F., STEINKE, D. & VENCES, M., 2005. – New amphibians and global conservation: a boost in species discoveries in a highly endangered vertebrate group. *BioScience*, **55**: 693-696.

LAMOTTE, M., (ed.), 1974. – *Le polymorphisme dans le règne animal. Mém. Soc. zool. Fr.*, **37**: 1-562.

LANNOO, M., 2005. – *Amphibian declines. The conservation status of United States species.* Berkeley, University of California Press: i-xxi + 1-1094.

LECOMTE, J., BIGAN, M. & BARRE, V., (ed.), 1990. – *Réintroductions et renforcements de populations animales en France. Rev. Ecol. (Terre & Vie)*, Suppl. **5**: 1-350.

MAYR, E., 1982. – *The growth of biological thought.* Cambridge, Mass. & London, Belknap Press: [i-xiii] + 1-974.

----- 1997. – *This is biology. The science of the living world.* Cambridge, Mass. & London, Belknap Press: i-xvii + 1-327.

MILLER, C. R., WAITS, L. P. & JOYCE, P., 2006. – Phylogeography and mitochondrial diversity of extirpated brown bear (*Ursus arctos*) populations in the contiguous United States and Mexico. *Molecular Ecology*, in press.

PÄÄBO, S., 2000. – Of bears, conservation genetics, and the value of time travel. *Proc. natn. Acad. Sci. USA*, **97**: 1320-1321.

PAGANO, A., DUBOIS, A., LESBARRÈRES, D. & LODÉ, T., 2003. – Frog alien species: a way for genetic invasions? *Comptes rendus Biologies*, **326** (suppl. 1): S85-S92.

PASCAL, M., LORVELEC, O. & VIGNE, J.-D., 2006. – *Invasions biologiques et extinctions. 11000 ans d'histoire des Vertébrés en France.* Paris, Belin: 1-350.

RAPPE, A., 1977. – Conservation de la nature et réintroduction d'espèces. *L'Homme et l'Oiseau*, **15** (3): 94-98.

REILLE, A., 1990. – Les transplantations de macareux moine (*Fratercula arctica*). *In*: LECOMTE et al. (1990): 257-259.

ROSS, C. A., 1977. – Response to Bowler's letter on alligators. *Herp. Rev.*, **8**: 37.

STUART, S. N., CHANSON, J. S., COX, N. A., YOUNG, B. E., RODRIGUES, A. S. L., FISCHMAN, D. L. & WALLER, R. W., 2004. – Status and trends of amphibian declines and extinctions worldwide. *Science*, **306**: 1783-1786.

TABERLET, P. & BOUVET, J., 1994. – Mitochondrial DNA polymorphism, phylogeography, and conservation genetics of the brown bear *Ursus arctos* in Europe. *Proc. biol. Sci.*, **255**: 195-200.

TERRASSE, M., 1990. – Réintroduction du vautour fauve dans les Grands Causses et renforcement de population du vautour percnoptère. *In*: LECOMTE et al. (1990): 213-225.

VASSEROT, J., 1972. – Possibilités offertes par la Bretagne pour l'acclimatation de Reptiles et de Batraciens. *Penn ar Bed*, **19**: 177-196.

Corresponding editor: Annemarie OHLER.